DLR Contribution to the first High Lift Prediction Workshop – Part I

R. Rudnik, S. Melber-Wilkending, S. Crippa

DLR, Institute of Aerodynamics and Flow Technology, D-38108, Braunschweig, Germany

DLR motivation for workshop participation

- **Extend validation and verification of the DLR TAU-code's predictive capabilities for a 'new' 3D high lift test case**

- **Benchmark hybrid unstructured grid generation approaches, namely CENTAUR/TAU vs. SOLAR/TAU for a 3D high lift configuration**
  - **consideration of gridding guidelines for high lift cases**
  - **check prism-dominant vs. hex-dominant near wall grid topologies**
  - **grid refinement study for 3D configuration**

- **Check/improve best practice approaches for complex high lift configurations**
  - **turbulence model performance**
  - **convergence start-up procedure**
  - **efficiency aspects, simplifications (e.g. b.t.e. resolution)**

⇨ **Focus on CENTAUR-TAU and case 1**

CASE 1

CENTAUR/TAU

CENTAUR Grid Family

Grid Generation - CENTAUR

- Grid family approach with 3 levels (initially 4)
- Grid level characteristics

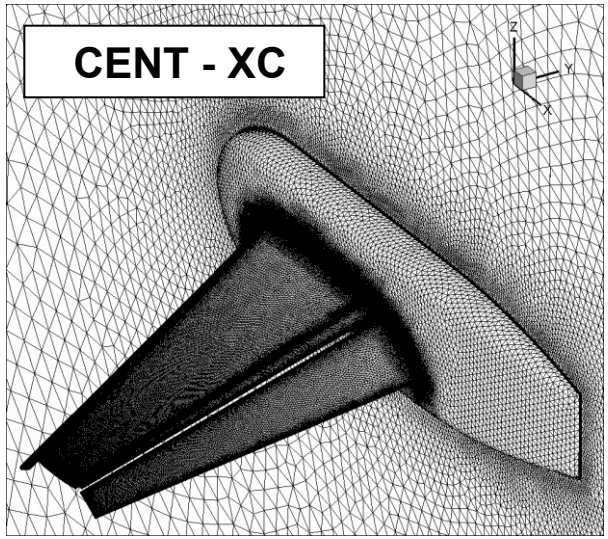
Grid Level	Pts.	Prisms	Surf. Elem.	Tot. Elem.
XC	12,923,391	19,288,488	695,194	37,418,633
C	16,374,761	26,509,026	865,844	43,548,725
M	31,498,984	53,614,403	1,596,988	78,725,517

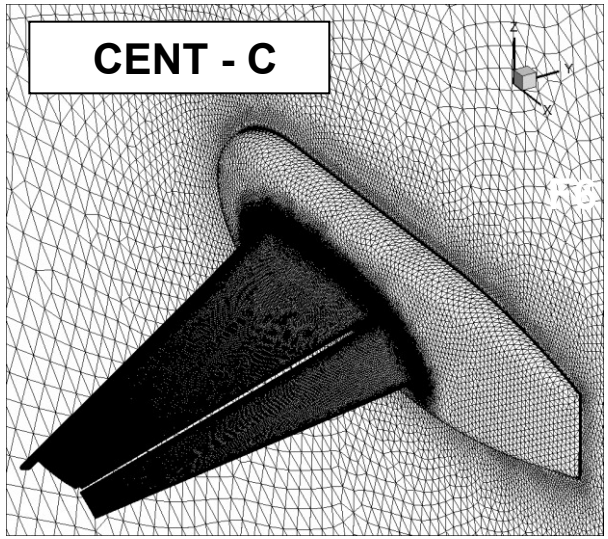
- Grid generation and adaptation approach
  - y^+ -adaptation sectionwise and spanwise
  - adjustment of prism layer thickness sectionwise and spanwise
  - spanwise adaptation of streamwise surface resolution at l.e. and t.e.
  - additional refinement by local cylinder sources along trim curves at root and tip

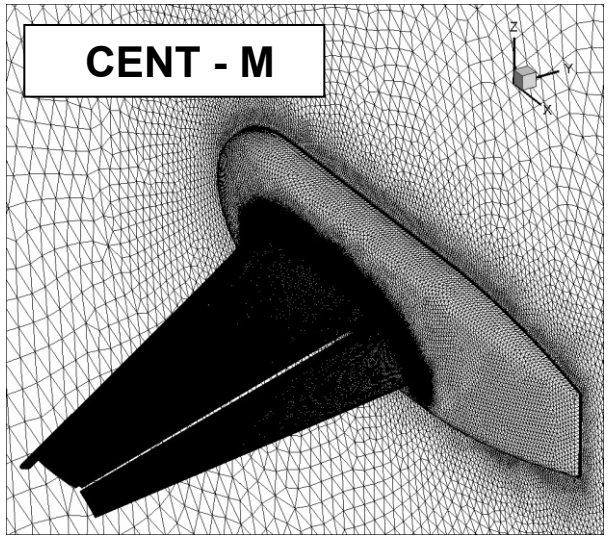
Grid Generation - CENTAUR

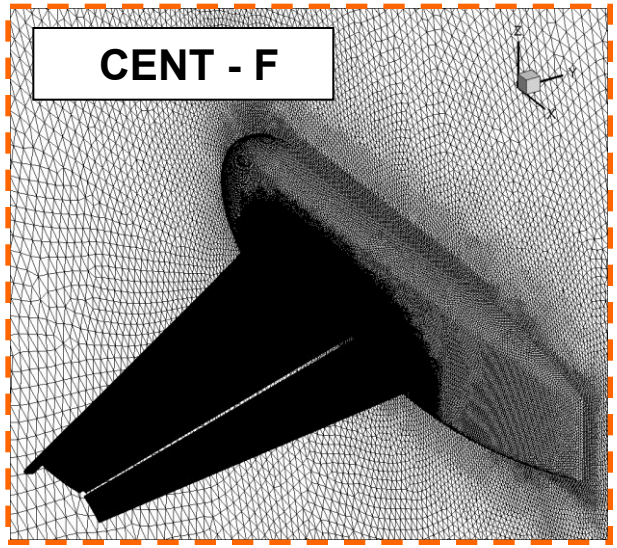
- Grid generation approach – HiLiftPW-special features / lessons learned
  - B.t.e. resolution requires CAD-repatching on t.e. to account for specif. resolution (cut, reorganize and join in 50 spanwise section)
  - Parametric Source Control in order to better
    - introduce sectionwise requirements along span
    - control wall normal stretching of prisms and surface resolution requirements
    - to achieve smooth cell growth distribution
    - automated transfer to different grid levels
    - allow for handling of multiple (~2.000+) single grid sources
- DLR fine grid problem using CENTAUR:
  - surface and near wall areas successfully resolved with prisms
  - outer prism layer characterized by large cell (surface) aspect ratios
  - failure to connect with tets due to cell AR and requirement for constant volume ratio
  - automatic ability to locally adjust number of prisms, spanwise anisotropy and surface resolution

- **Surface grid - configuration - rear view**

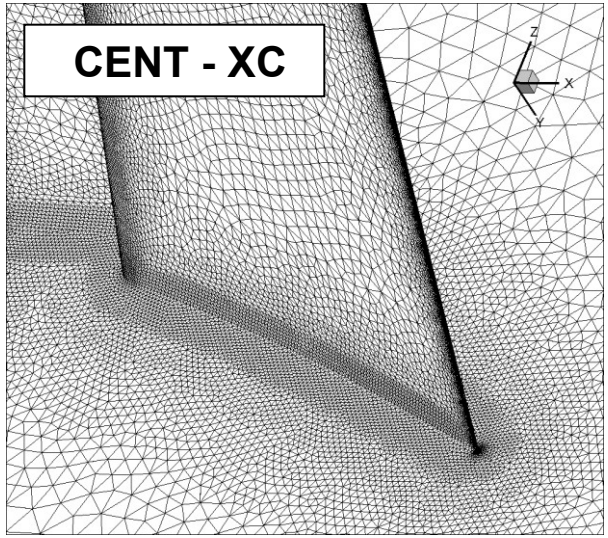


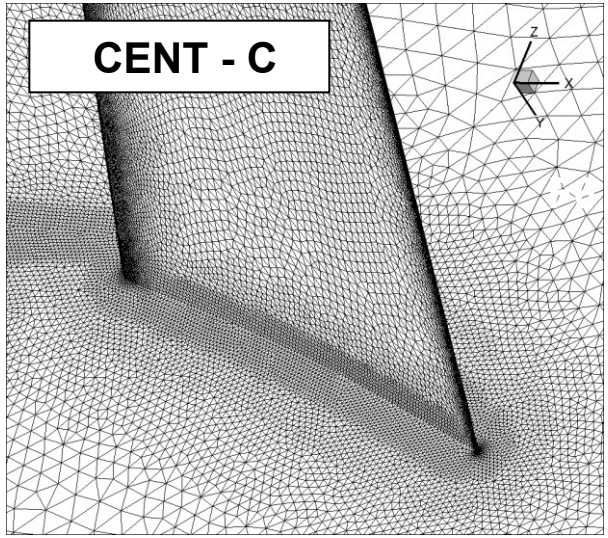


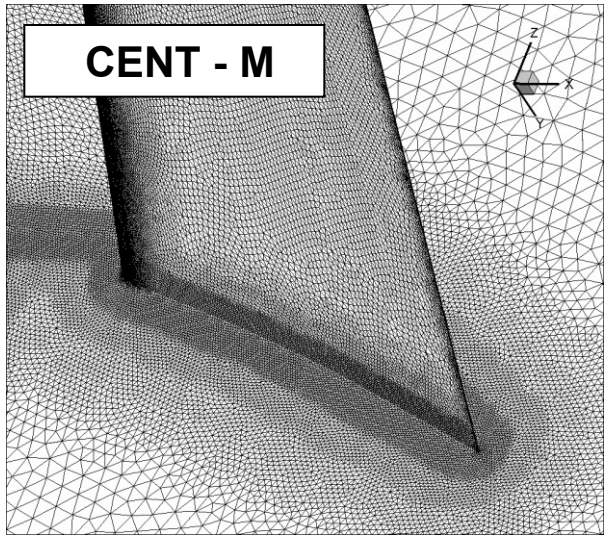


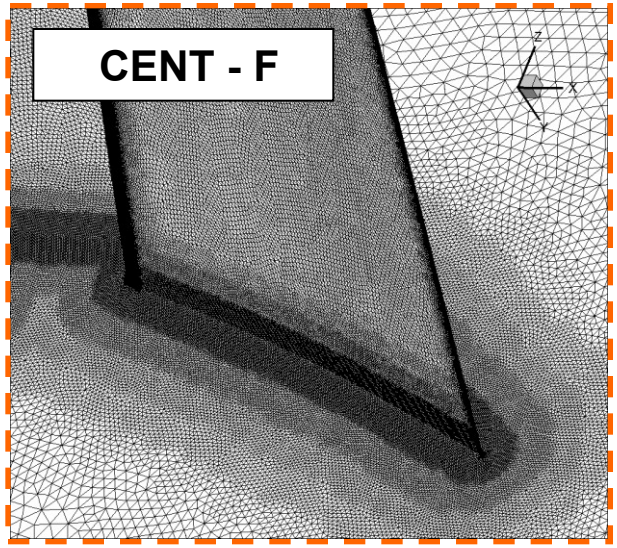


- **Surface grid - WB-junction flap - lower side view**

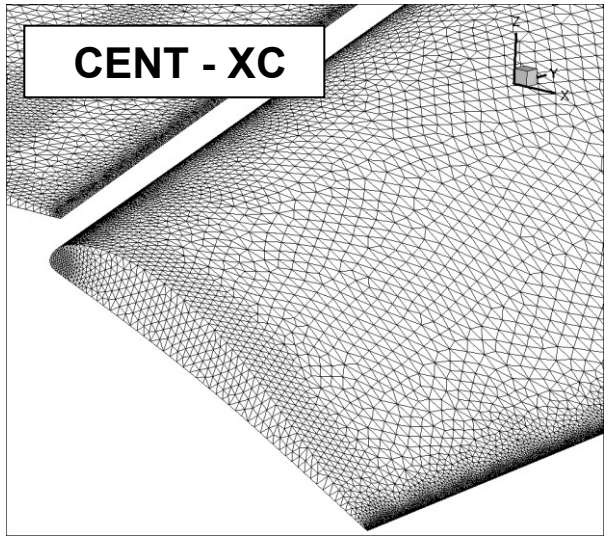


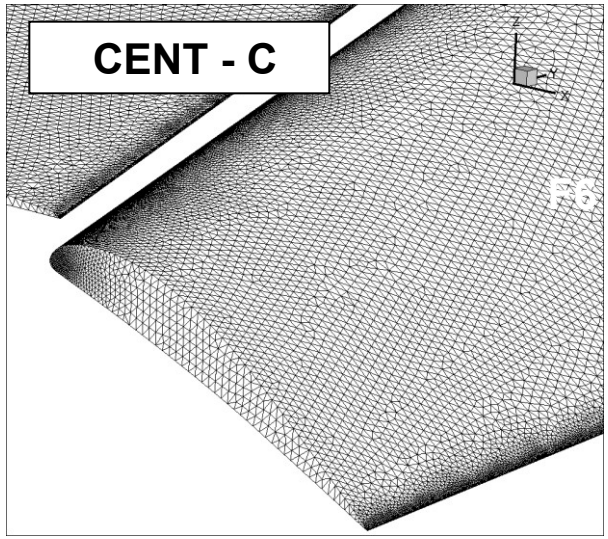


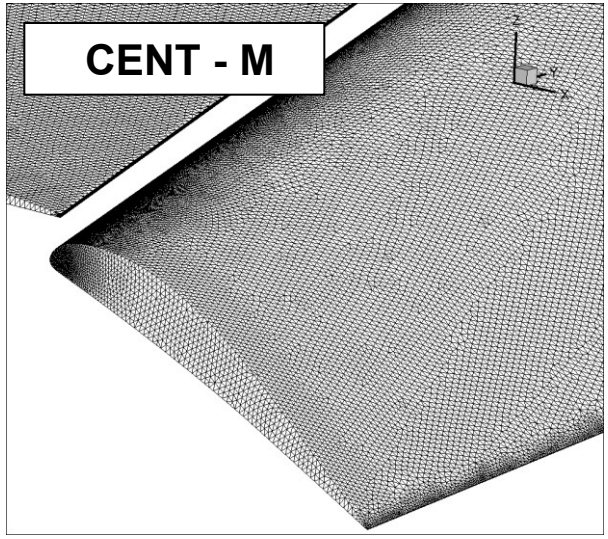


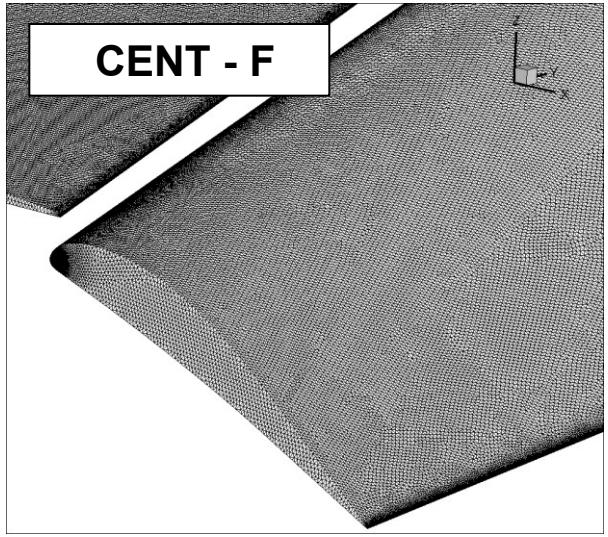


- **Surface grid - flap tip - upper side view**

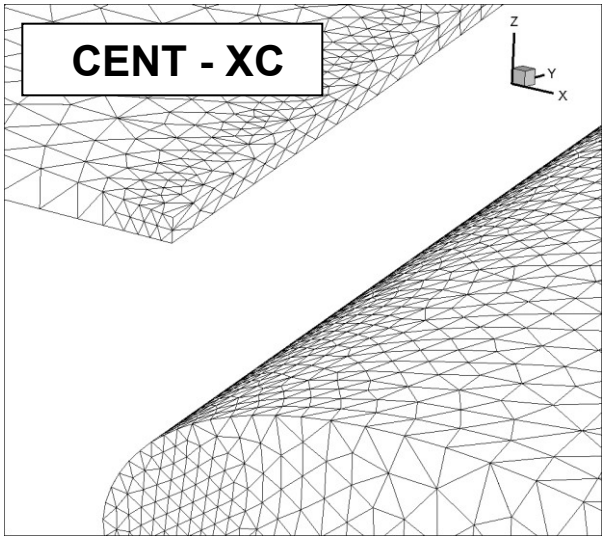


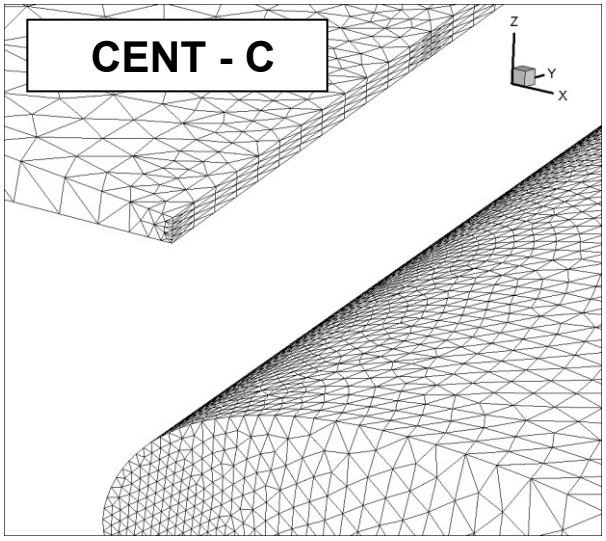


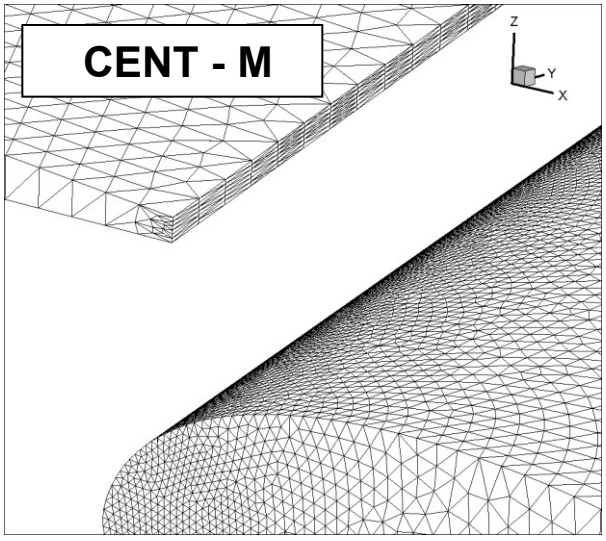


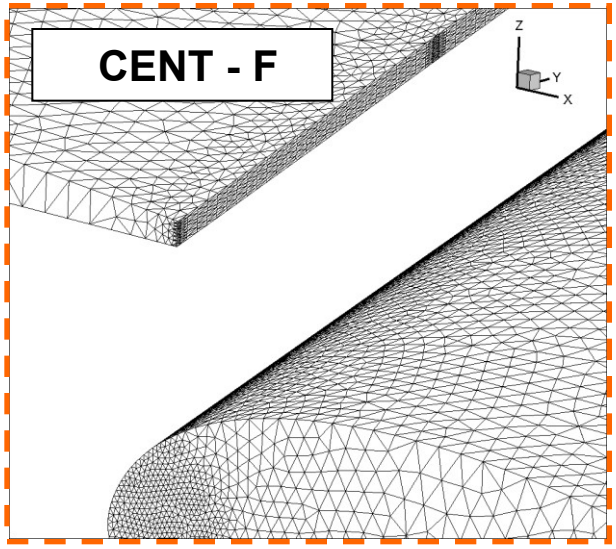


- **Surface grid – wing t.e., flap gap - upper side view**



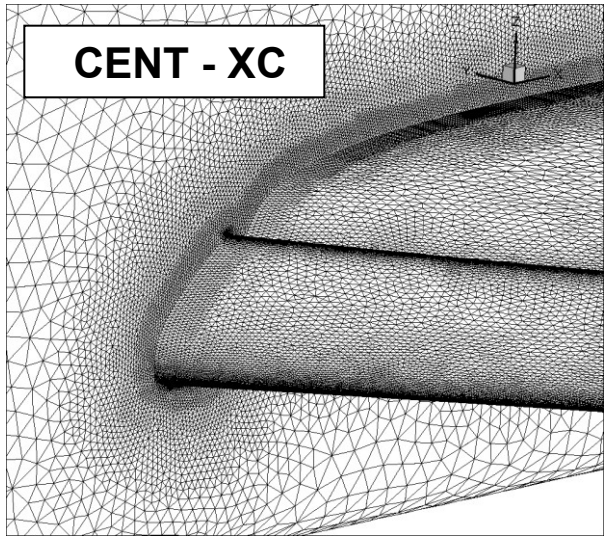


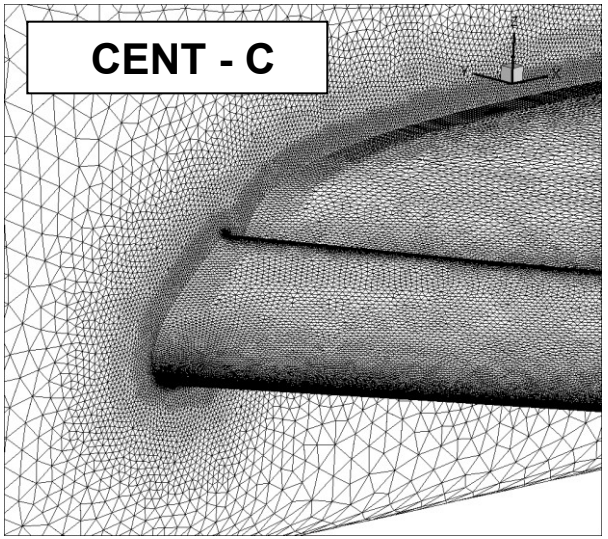


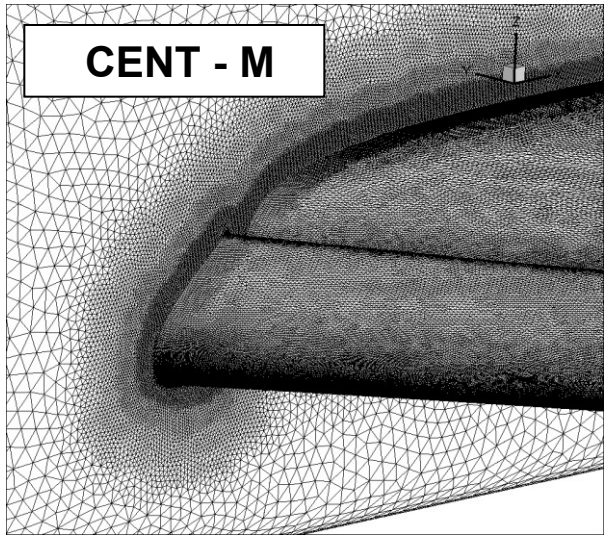


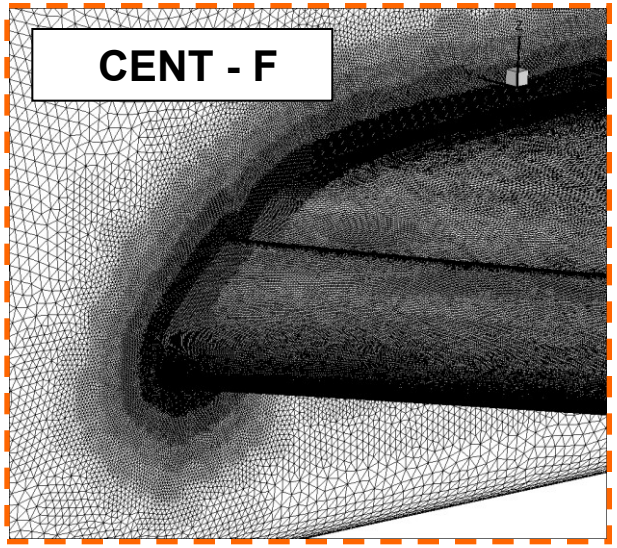
Grid Generation – CENTAUR, Grid Family

- **Surface grid - WB-junction, slat, wing - upper side view**









CASE 1

CENTAUR/TAU

Baseline CFD Results – Medium grid

TAU Computations – Parameter-Settings

- **Code Version:** DLR TAU code 2010.1.0

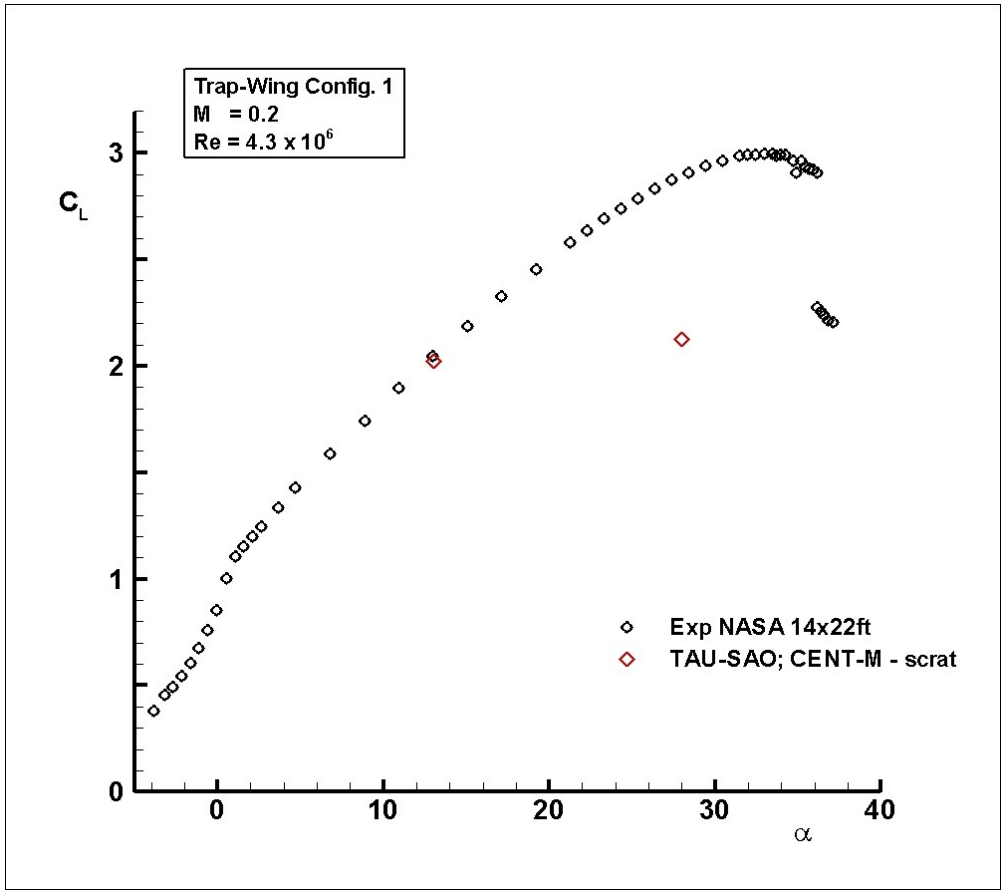
- **Spatial Discretization:**
  - **Main equations:** Jameson central, 2nd order;
    Blend scalar (80%) – matrix (20%) dissipation
  - **Turb. Equations:** Roe upwind, 2nd order

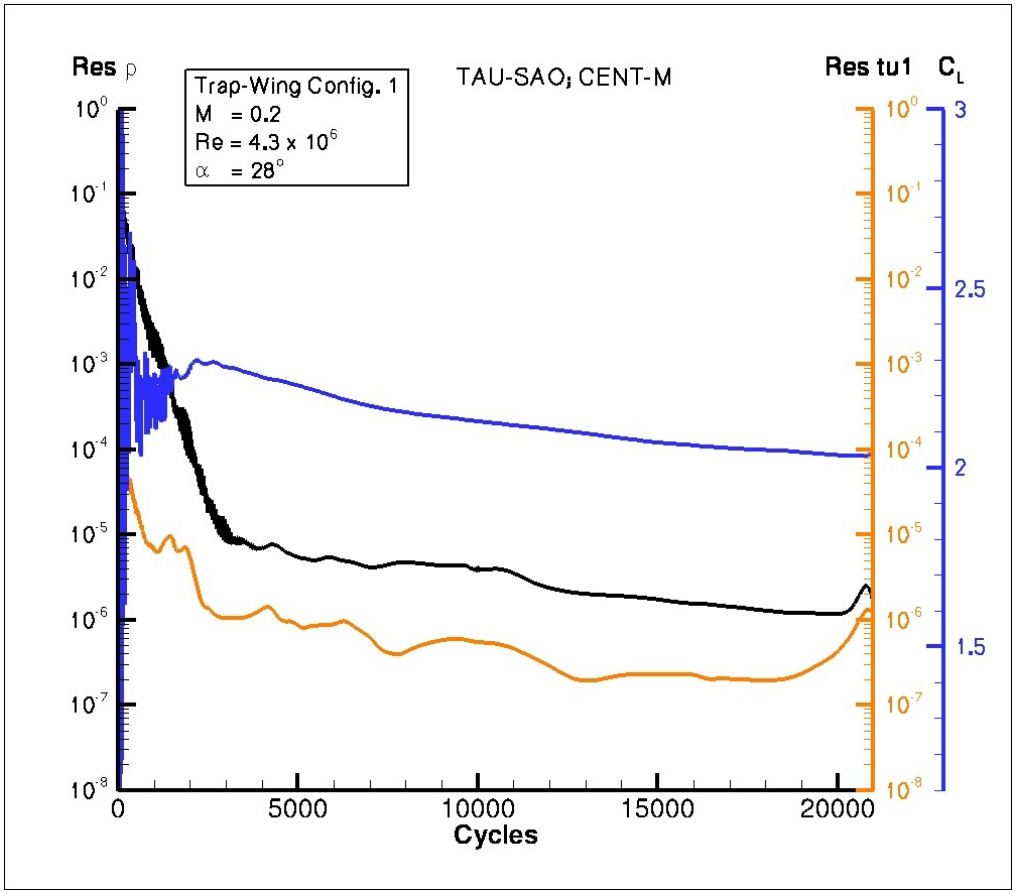
- **Turbulence Models:**
  - Spalart-Allmaras, original formul. (SAO)
  - Menter k-ω SST (SST)
  - SSG/LRR-ω diff. Re-stress model (RSM)

- **Temp. Integration:**
  - LU-SGS Backward Euler
  - Multigrid, 3V cycle

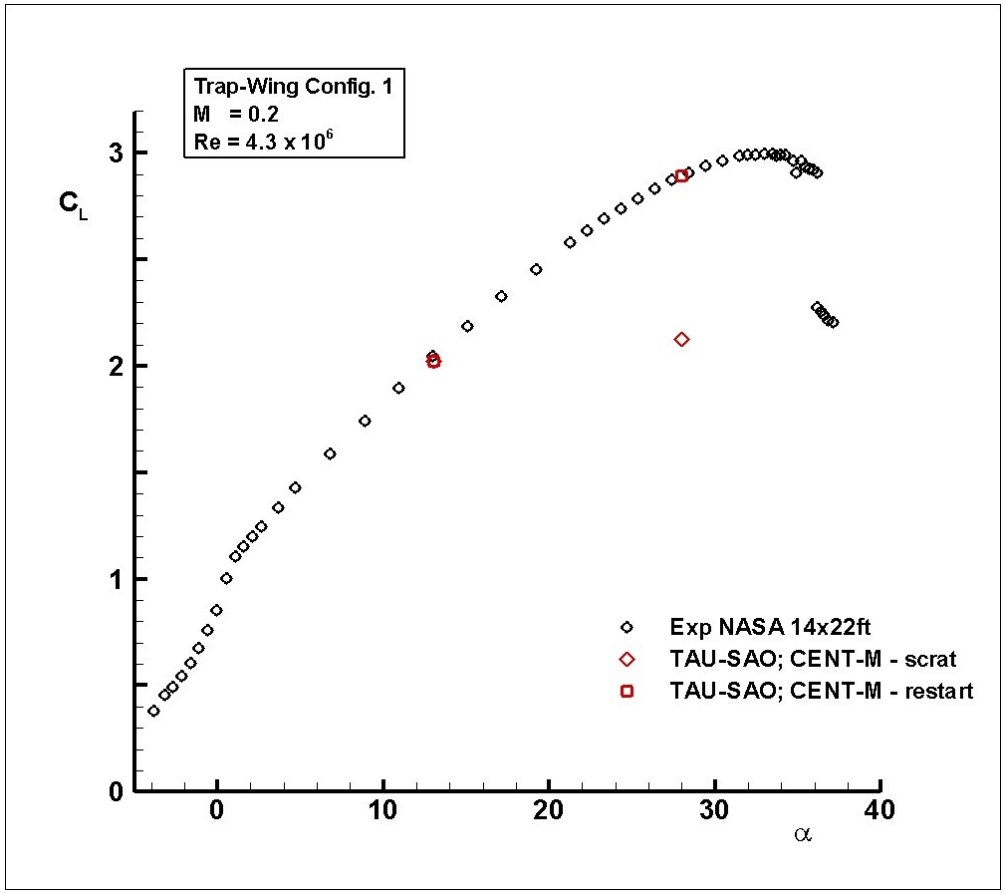
TAU-Computations – CENTAUR Grid - Case 1

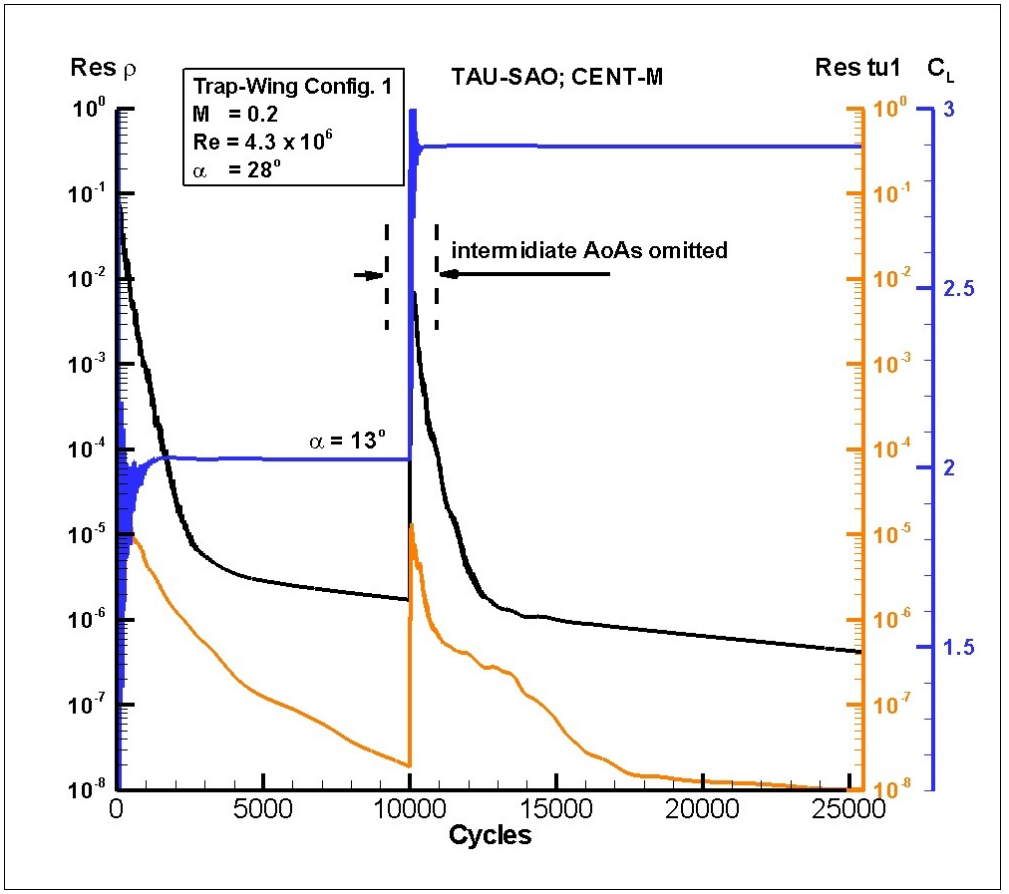
- **TAU-SAO, grid-m; α = 13, 28°: start-up procedure: scratch**



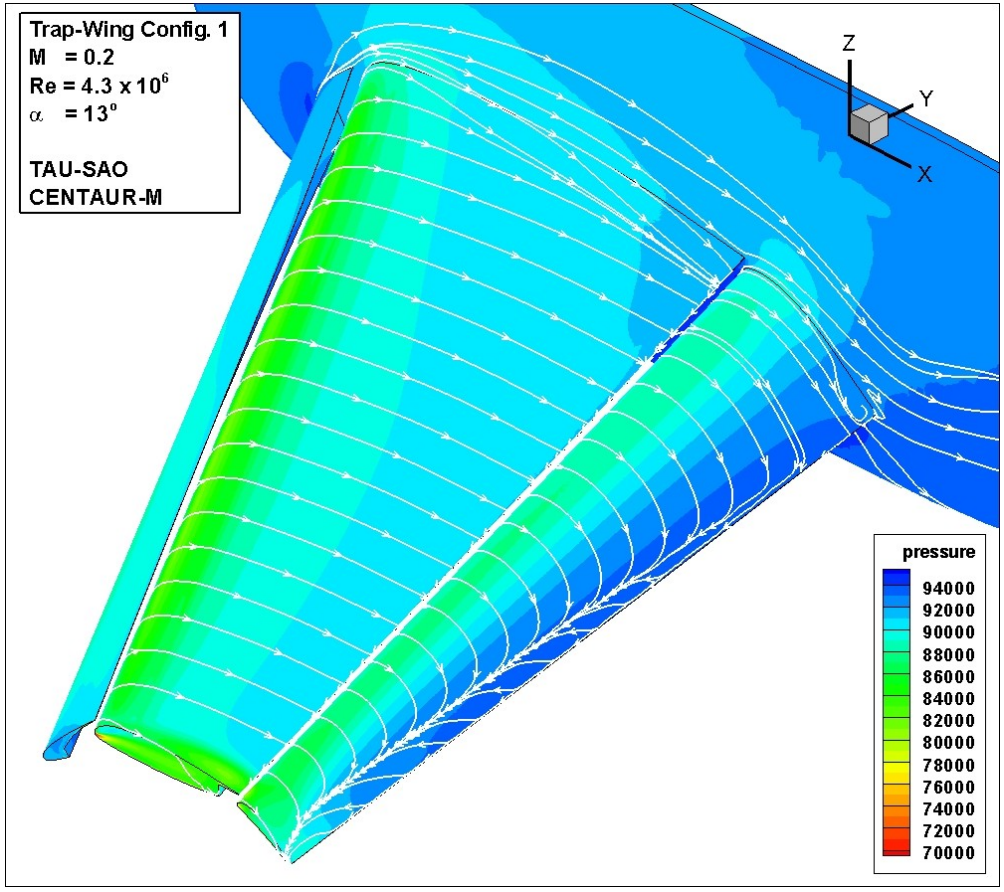


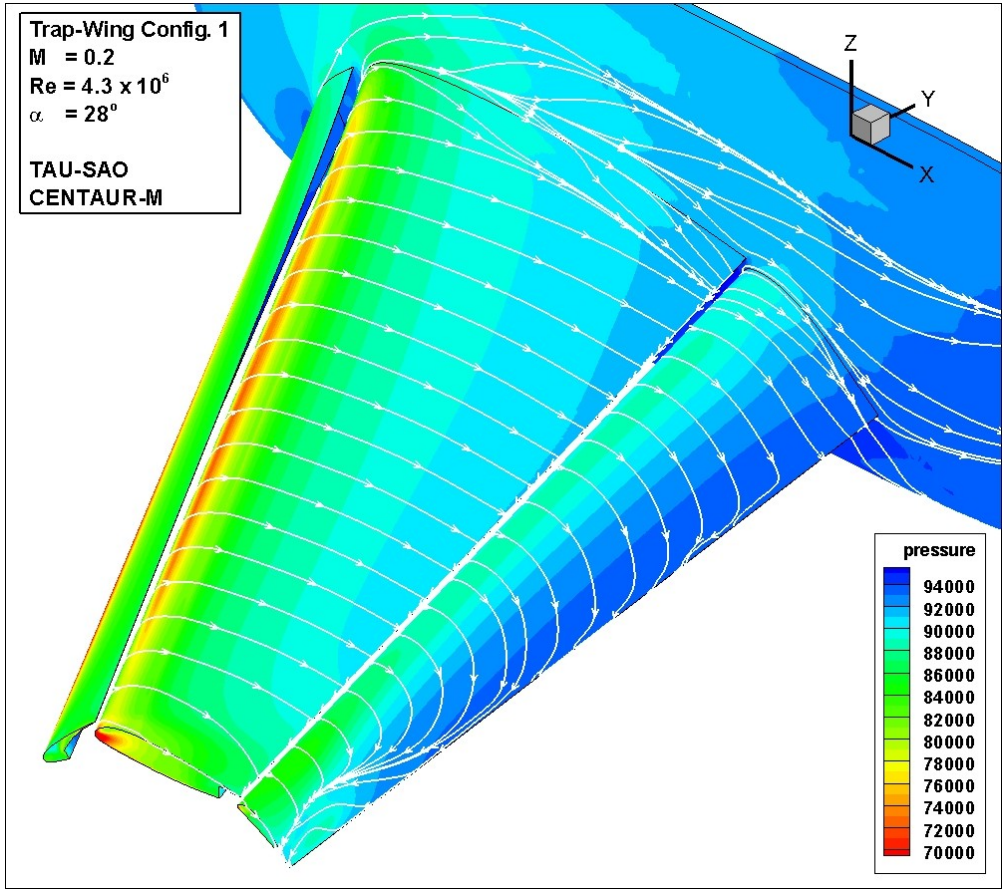
- **TAU-SAO, grid-m; α = 13, 28°: start-up procedure stepwise restart ($\Delta\alpha$ = 2°)**



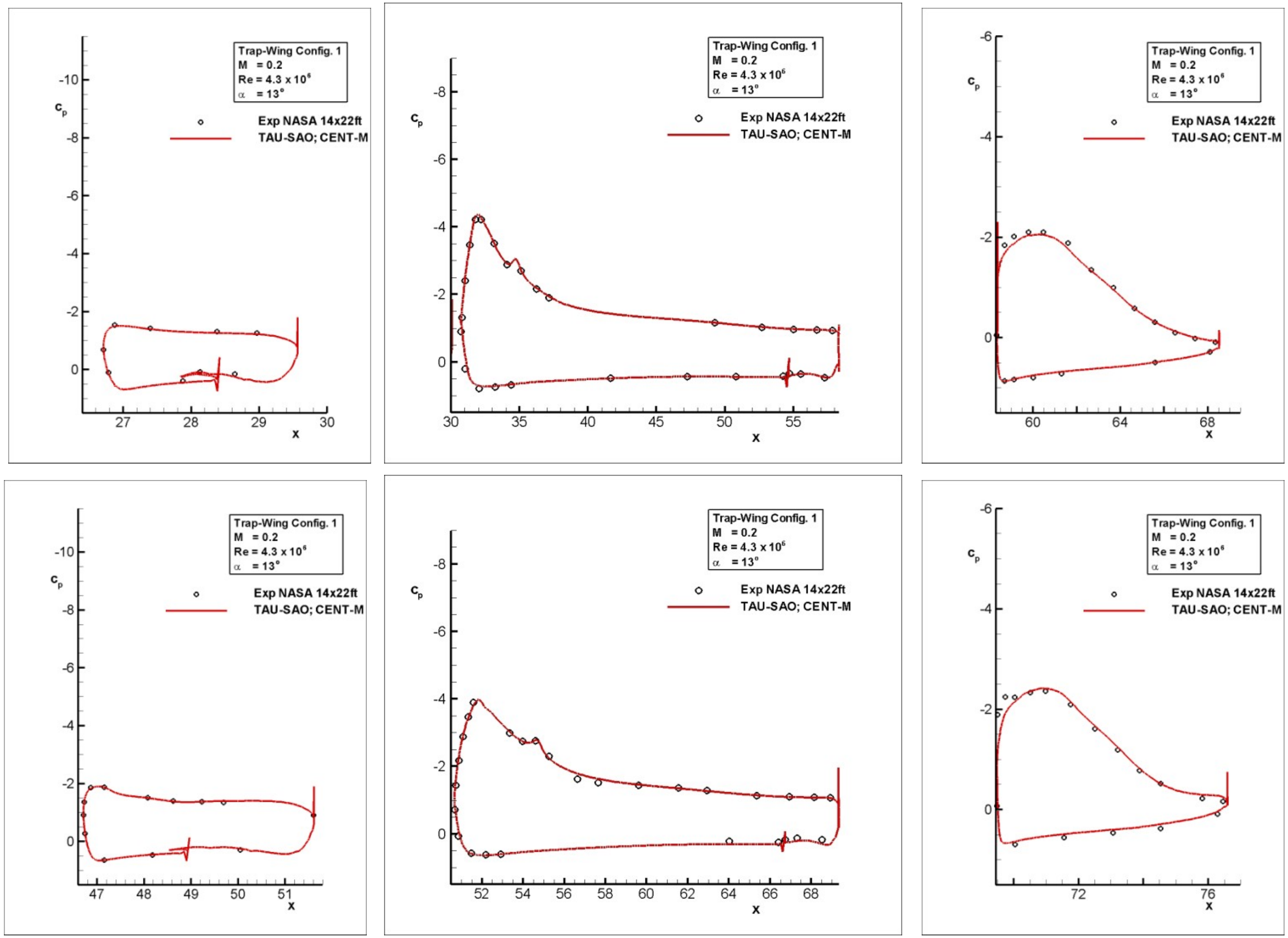


- **TAU-SAO, grid-m; α = 13, 28°: isobars and surface streamlines**



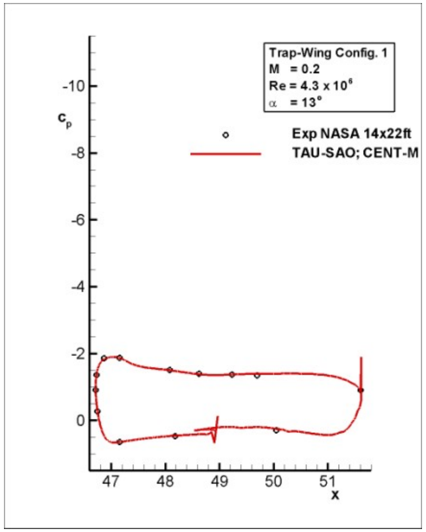


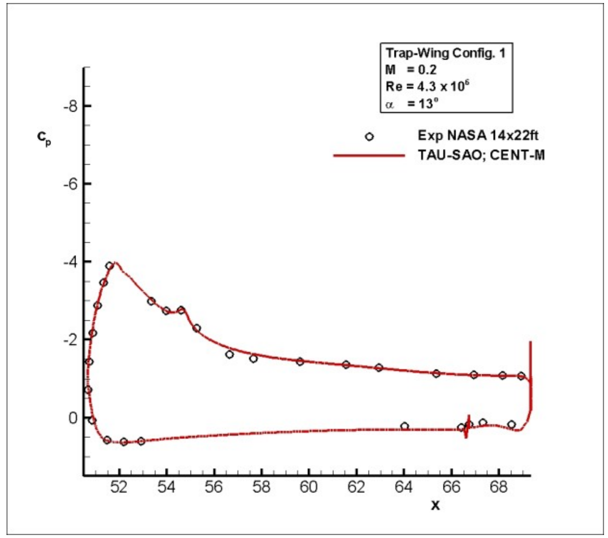
- **TAU-SAO, grid-m; α = 13°: pressure distribution at η = 0.50 and 0.85**

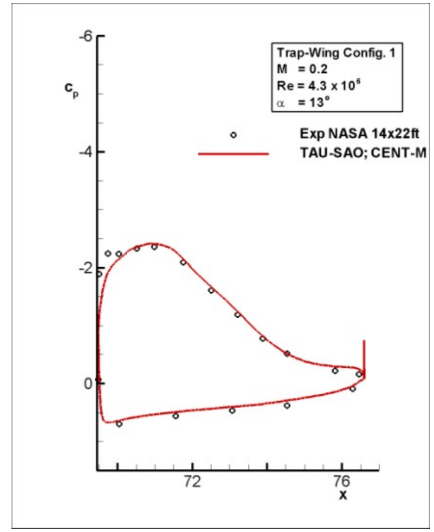


TAU-Computations – CENTAUR Grid - Case 1

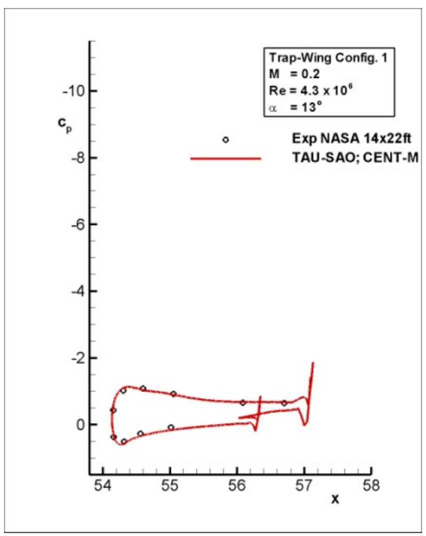
- **TAU-SAO, grid-m; α = 13°:** **pressure distribution at**

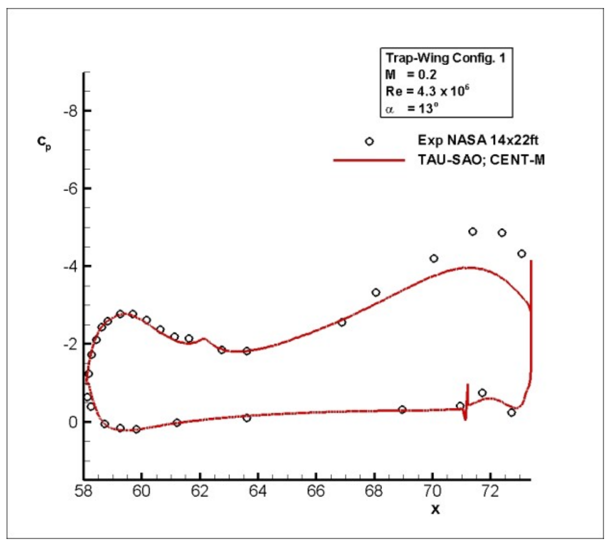


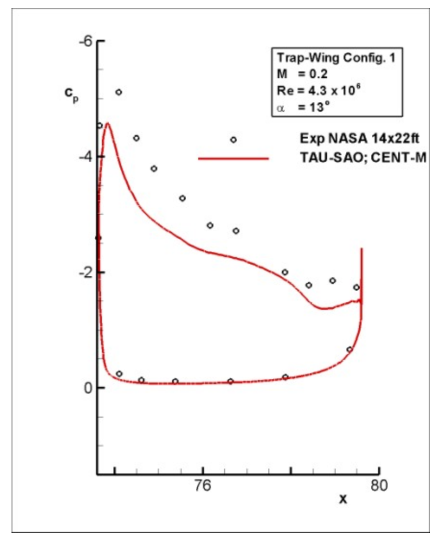




η = 0.85







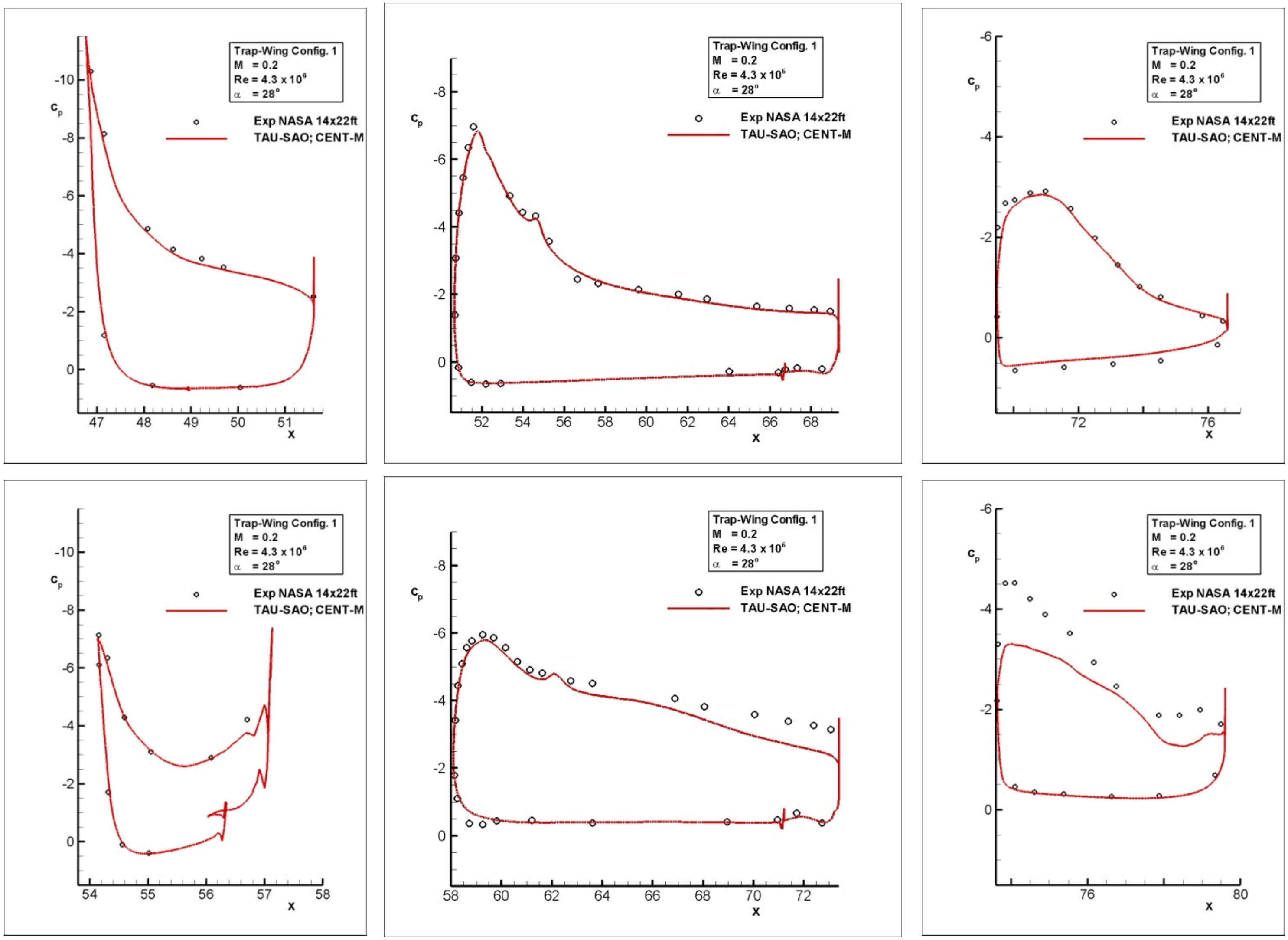
and 0.98

DLR

TAU-Computations – CENTAUR Grid - Case 1

CFD High Lift Prediction Workshop

- **TAU-SAO, grid-m; α = 28°:** **pressure distribution at**



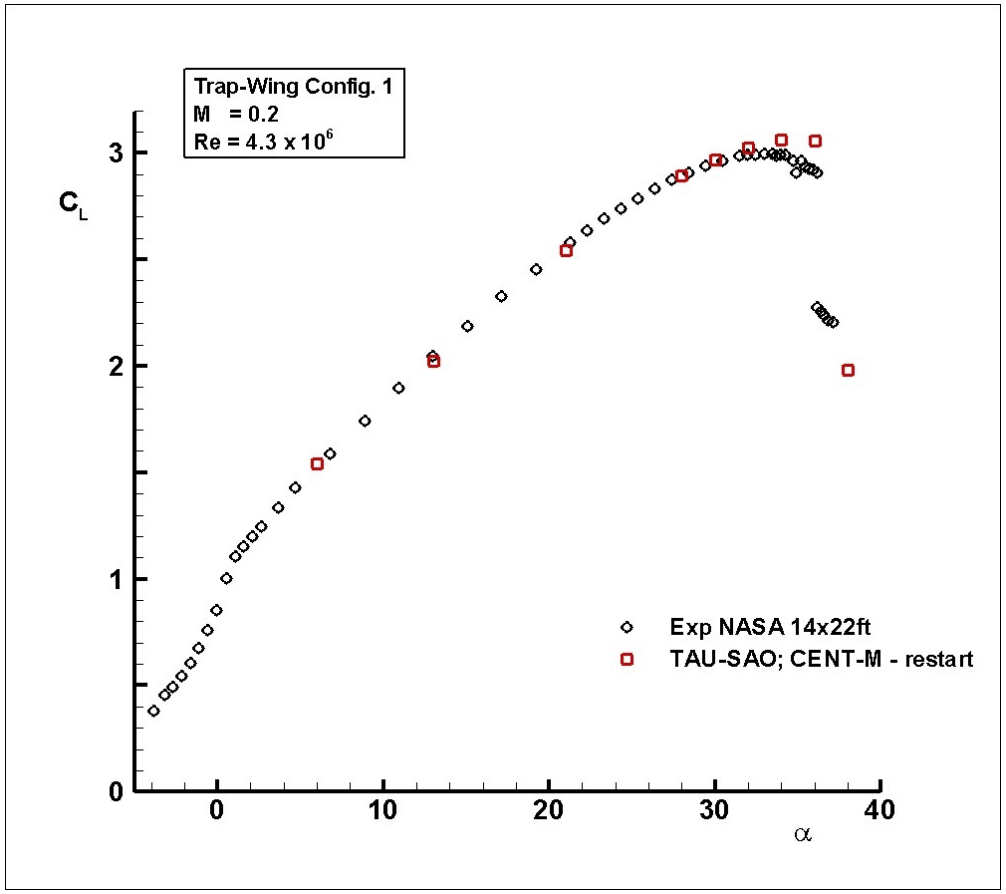
η = 0.85

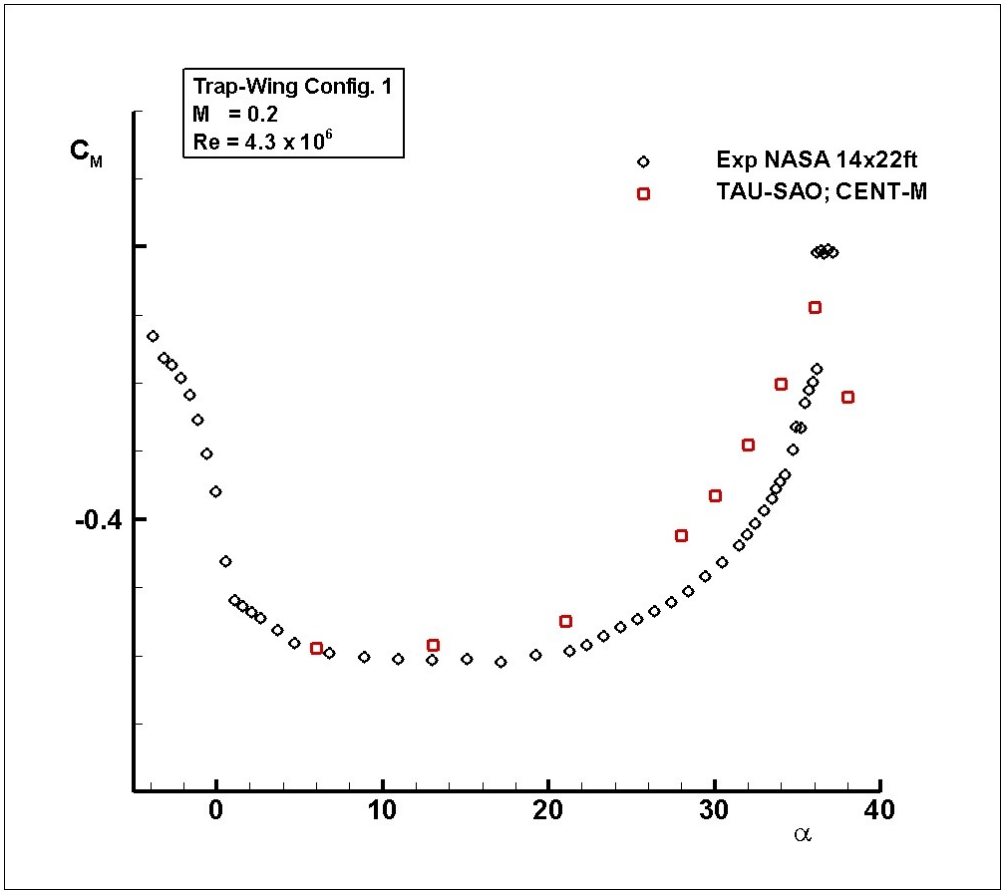
and 0.98

Rudnik

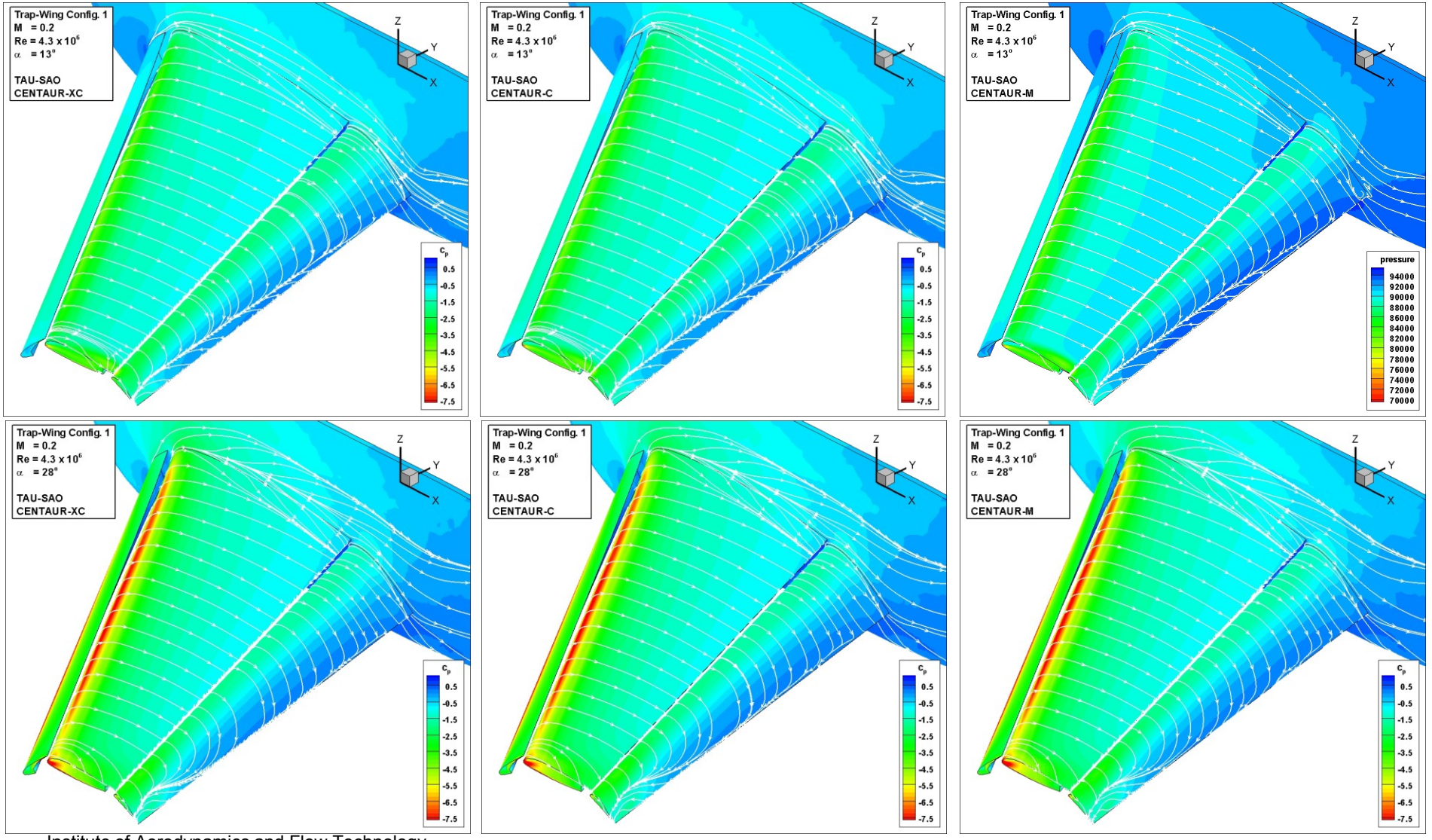
TAU-Computations – CENTAUR Grid - Case 1

- **TAU-SAO, grid-m; polar data**



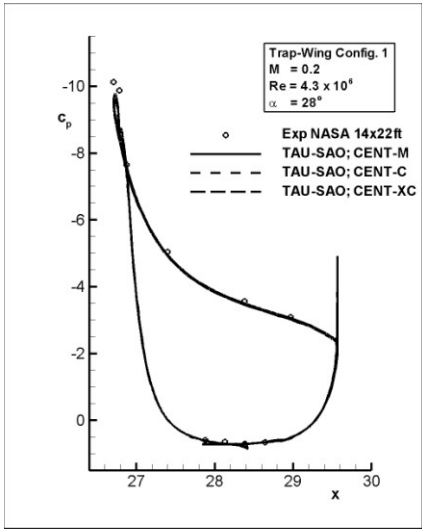


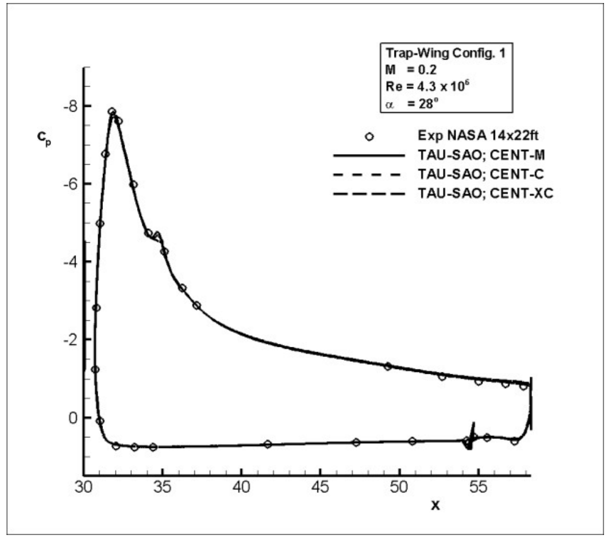
- TAU-SAO, grid-m; α = 13, 28°: isobars and surface streamlines

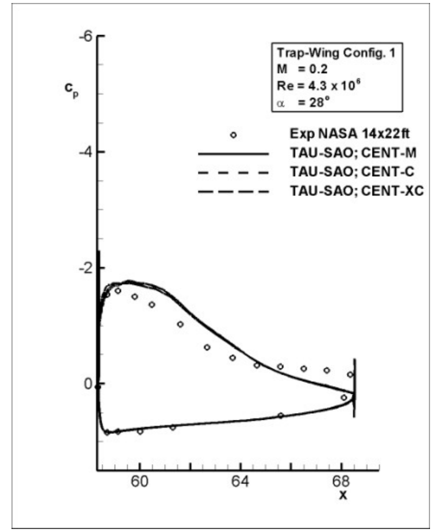


TAU-Computations – CENTAUR Grid - Case 1

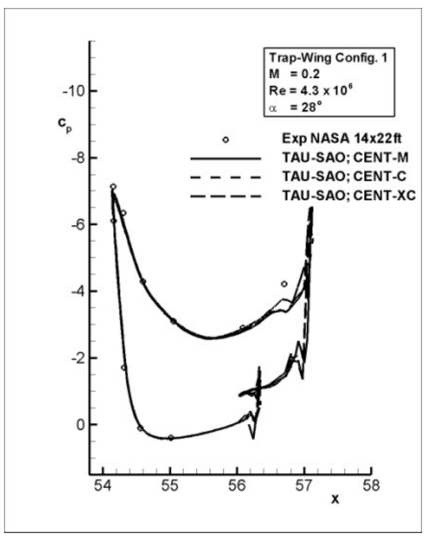
- **TAU-SAO, grid-family; $\alpha = 28^o$:** **pressure distribution at**

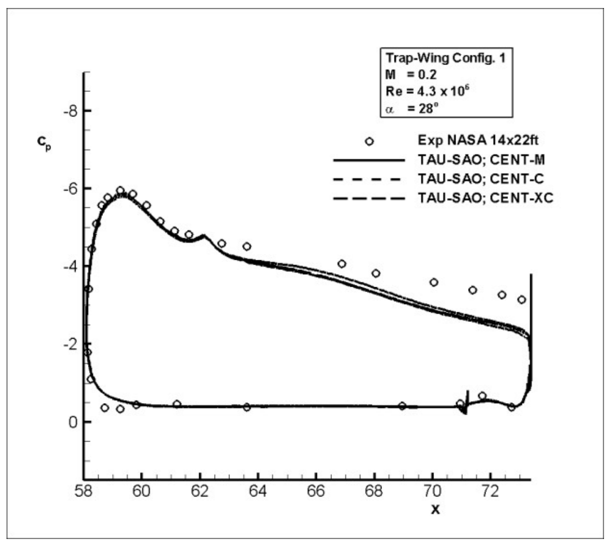


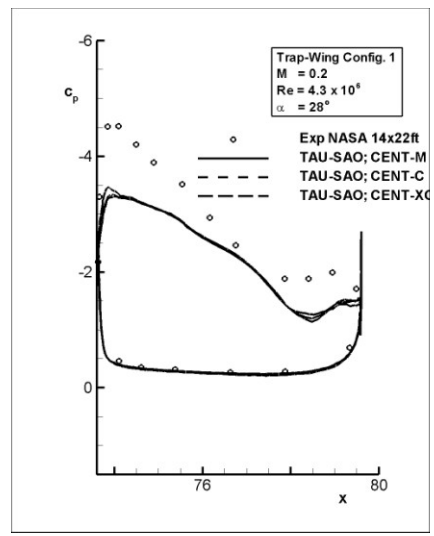




$\eta = 0.50$



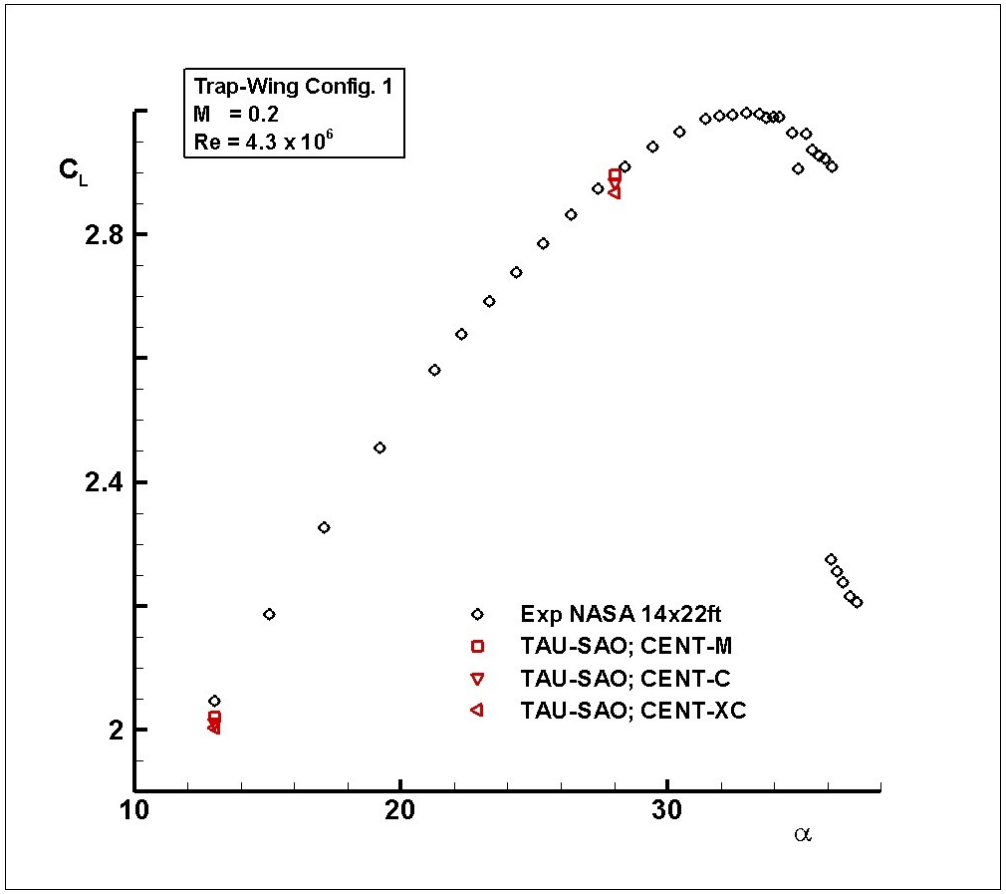


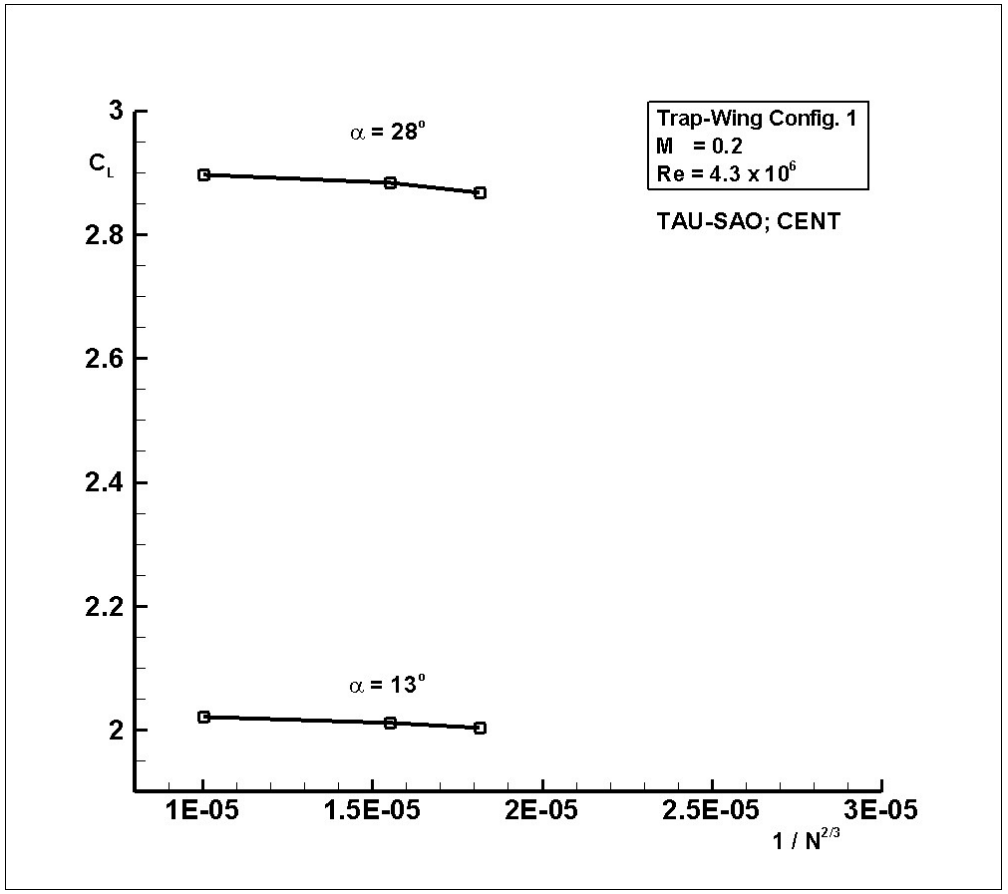


and 0.98

TAU-Computations – CENTAUR Grid - Case 1

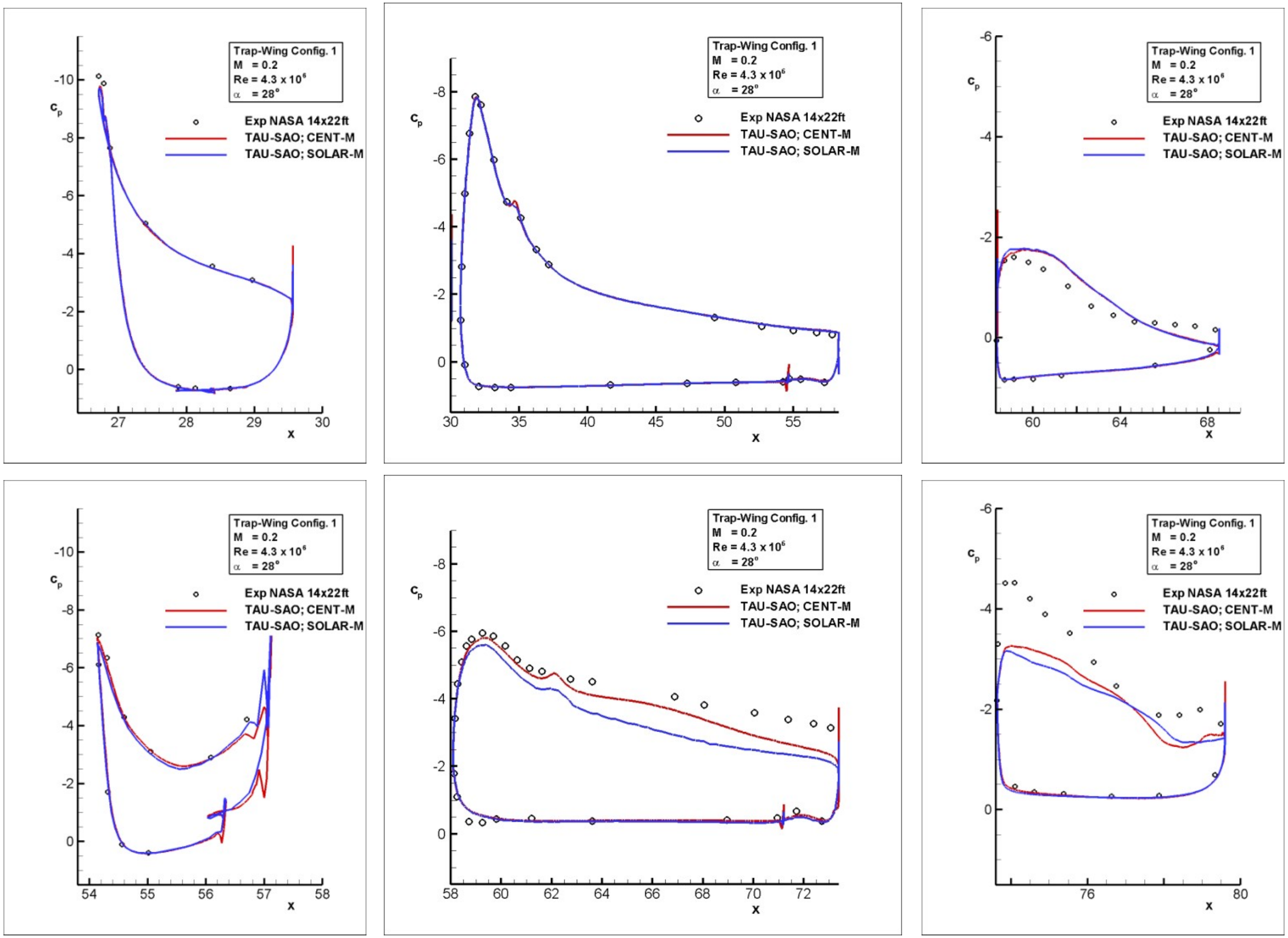
- **TAU-SAO, grid-family; α = 13, 28^o : lift force dependency**





TAU-Computations – CENTAUR Grid - Case 1

- **TAU-SAO, grid-n; $\alpha = 28^o$: CENT/TAU vs. SOLAR/TAU pressure distribution at**

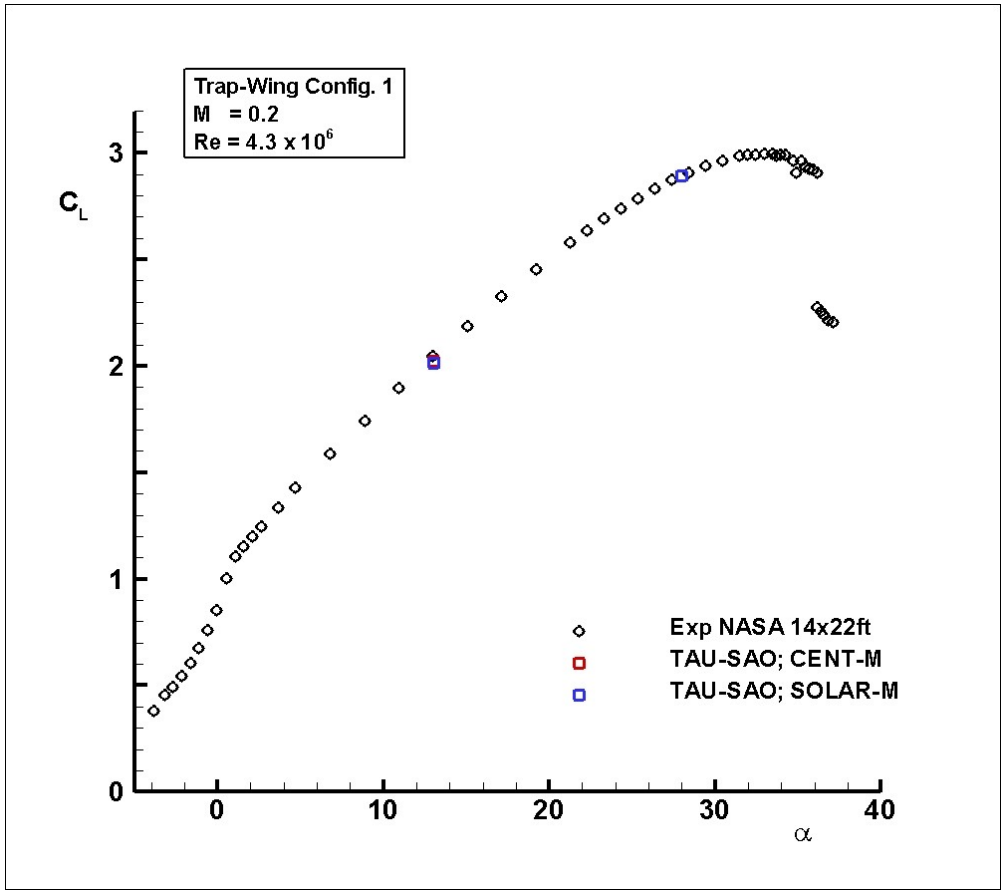


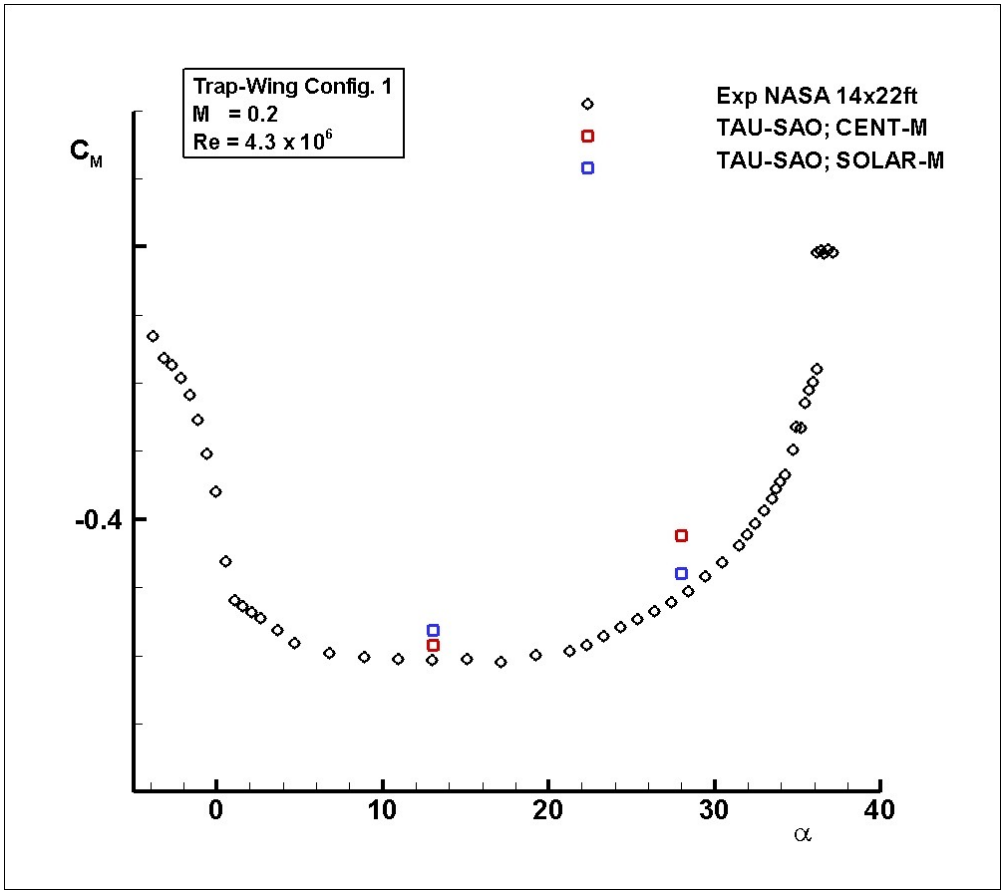
η = 0.50

and 0.98

TAU-Computations – CENTAUR Grid - Case 1

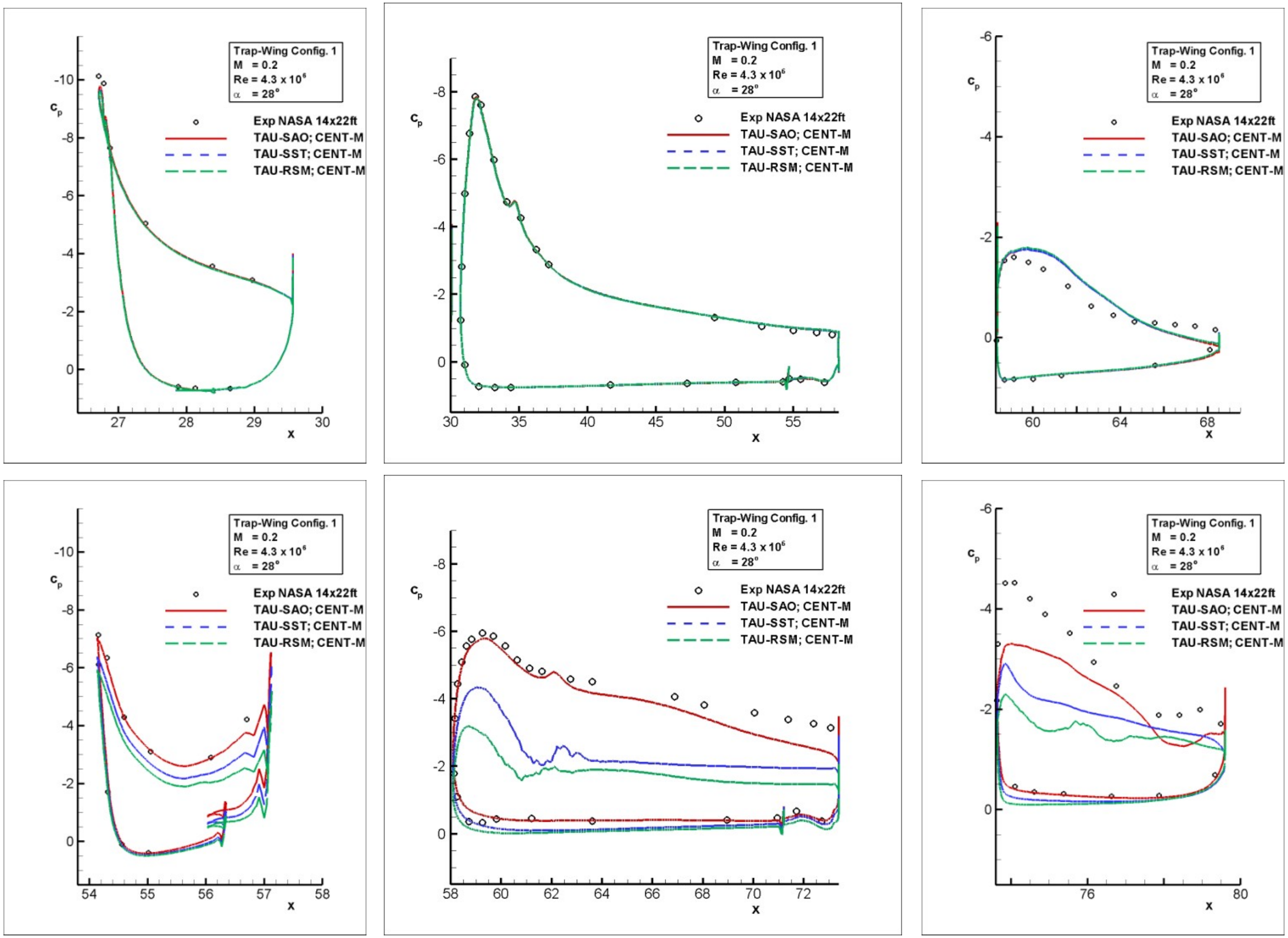
- **TAU-SAO, grid-m; α = 13, 28^o ; CENT/TAU vs. SOLAR/TAU**





TAU-Computations – CENTAUR Grid - Case 1

- **TAU-SAO, grid-n; α = 28°: turb.-model-var.** **pressure distribution at**

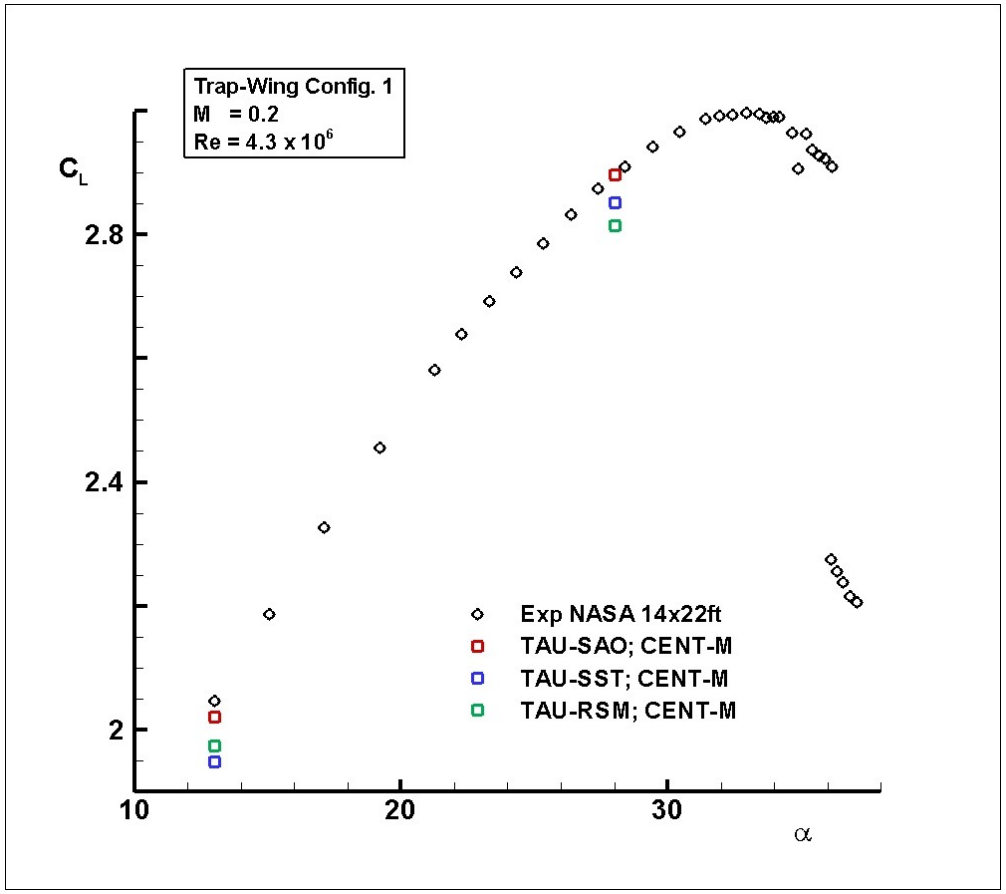


η = 0.50

and 0.98

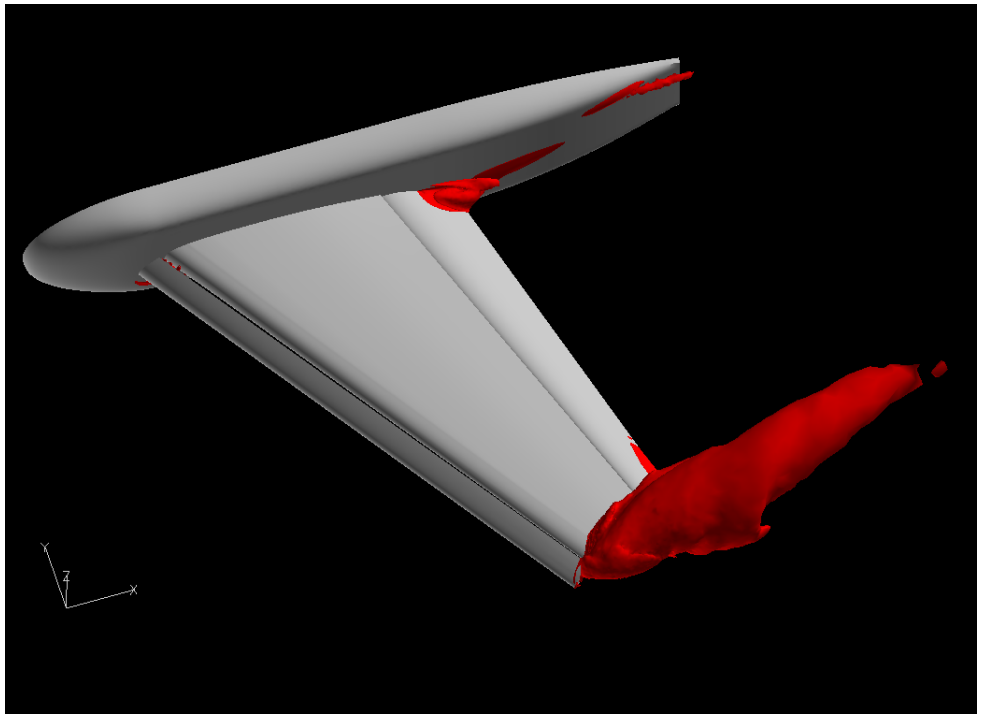
TAU-Computations – CENTAUR Grid - Case 1

- **TAU-SAO, grid-family; α = 13, 28^o : turb.-model var.**



- TAU, grid-m; $\alpha = 13^{o}$: Velocity difference field plots

TAU (SAO-SST)



TAU (SAO – RSM)